

Investigation of surface roughness and tool wear length with varying combination of depth of cut and feed rate of Aluminium alloy and P20 steel machining.

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Abstract. High-speed milling technique is often used in many industries to boost productivity of the manufacturing of high-technology components. The occurrence of wear highly limits the efficiency and accuracy of high-speed milling operations. In this paper, analysis of high-speed milling process parameters such as material removal rate, cutting speed, feed rate and depth of cut carried out by implemented to conventional milling. This experiment investigate the effects of varying combination of depth of cut and feed rate to tool wear rate length using metallurgical microscope and surface roughness using portable surface roughness tester after end milling of Aluminium and P20 steel. Results showed that feed rate significantly influences the surface roughness value while depth of cut does not as the surface roughness value keep increasing with the increase of feed rate and decreasing depth of cut. Whereas, tool wear rate almost remain unchanged indicates that material removal rate strongly contribute the wear rate. It believe that with no significant tool wear rate the results of this experiment are useful by showing that HSM technique is possible to be applied in conventional machine with extra benefits of high productivity, eliminating semi-finishing operation and reducing tool load for finishing.

1. Introduction

Nowadays, high spindle speed and higher feed rates required to maximize the production of the company [1]. Machining technique with the combination of high spindle speed, high feed rate and shallow depth of cut by high speed milling (HSM) machine is one of the new production technology [2,3]. By comparing this high productivity machine with conventional machine has a number of advantages, such as high efficiency, accuracy, quality of final workpieces, eliminate the secondary or semi-finishing process, increase of productivity, cut off of costs and machining time, better surface finish, eliminates the needs of coolant, reduce tool load for finishing operation and last but not least small chips are produced for easily cleaning purposes.

When the cutting speed is increases, it enables the HSM values give several advantages such as enlarging of the material removal rate and improving of the final surface finish as in Figure 1 but higher acceleration and deceleration rates, and spindle start and stop result in excessive wear which

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limits the efficiency and accuracy of the workpieces and also need for expensive and special machine tools with advanced spindle and controllers [2, 3, 4]. Moreover, tool wear is common in all the machining process and depends on the type of tool, rigidity of the machine tools, generation of heat and cutting parameters.

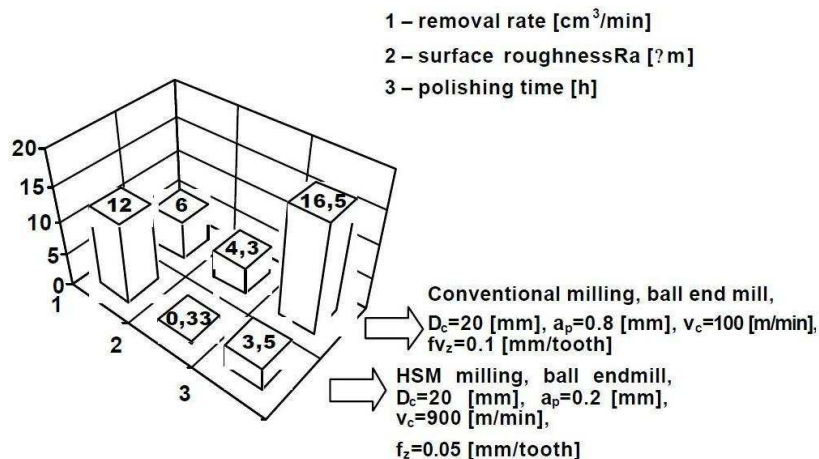


Figure 1: Comparison of production indexes during machining [2]

Apart from that, the possibilities of implementing high-speed milling technique in conventional milling machine exist at certain extent although with some limitations. Moreover, major limitations in conventional milling machines are the maximum spindle speed and feed rate that normally range from 4,000 rev/min to 10,000 rev/min and 5000 mm/min to 10,000 mm/min respectively compare with to high-speed milling machine where the spindle speed of 45,000 rev/min to 60,000 rev/min and feed rate of 30,000 to 40,000 mm/min are common. Normally, the optimum cutting parameters recommended by the tool manufacturer can be used in machining of specific material but in most of issues had to be adjusted to gain the desired machining output [3, 4, 5, and 6].

In addition, feed rate had significant influences on surface roughness value of machined surface. Furthermore, the data will be boosted with increasing of feed rate [12, 15]. Meanwhile, increase of feed rate and cutting speed contribute for the acceleration of material removal rate but normally will result in higher tool wear rate [14]. In fact, the increase cutting speeds wears the tool faster and reduces lifespan time of tool. Other than that, depth of cut is considered as not contributing significant influences to tool wear rate because the uncut chip thickness and average contact temperature is kept remain constant when the depth of cut increases [13]. Hence, the tool wear rate should not influenced by an increase in the depth of cut if the machining is conducted at the optimum cutting regime [3, 7].

Based on the review studied, it can be summarize that, a lot of experiment have been done using high-speed milling technique which could gain multiple of benefits as discussed earlier. Through the experiments, effect of machining parameters, feed rate and depth of cut on high speed technique application in conventional milling machine was analyzed. Furthermore, by implementing high speed milling technique to the conventional milling machine by using shallow depth of cut and high feed rate with constant spindle speed and material removal rate, staggered form produced at machined part having profile shape after roughing operation is nearly the final shape with excellent surface finish and good dimensional accuracy that can possibly eliminate the finishing or semi finishing process and reduce machining time and cost. At the same time, this can contribute to the possibility of machining of very thin walls, provide low cutting force and reduction of production process. Moreover, by increasing the maximum spindle speed, the output will be highly efficient, quality and accurate.

Besides that, these ensure the productivity of materials will be maximized and enables higher productivity owing.

2. Experimental setup

Two different types of materials are used in this experiment. There are Aluminium and P20 steel materials. After conducting squaring machining process using conventional milling machine on both materials, the experiment was began with single slot of pocket. The machining parameters used in the first experiment for Aluminium, began with depth of cut of 2mm and feed rate of 45 mm/min until the least depth of cut and highest feed rate of 0.08mm and 1500 mm/min respectively. For P20 steel material, the machining parameters began with the same depth of cut as Aluminium until least depth of cut but the feed rate began with 55 mm/min until the highest feed rate of 1100 mm/min. The spindle speed is constant for both materials that are 3000 rev/min. The size of pocket to be machined for both materials Aluminium and P20 are 73mm x 81mm x 30mm and 102mm x 104mm x 15mm respectively.

In the second experiment, the machining parameters began with ten slot of pocket with the same depth of cut and feed rate for both types of materials as in experiment one but extended until the least depth of cut and highest feed rate of 0.03mm and 3000 mm/min respectively. In fact, there is an increment of spindle speed to 3500 rev/min and kept constant for both materials. Other machining parameters were set to be constant which are radial depth of cut of 60% overlap ratio and material removal rate. Apart from that, constant material removal rate was determined from tool path simulation using Catia V5R20 software that recommended various depth of cut and feed rate combination in order to get same machining time which too means the same material removal rate for each set of experiments. The actual machining time were checked after each completion of machining experiment to verify constant material removal rate after actual machining with the tolerance of ± 5 minute.

After that, the generated NC code from Catia V5R20 then transferred to the conventional milling machine used which known as Makino KE55, 3-axis milling machine with maximum spindle speed of 4000 rev/min and feed rate of 5000 mm/min respectively. Moreover, the insert used was flat end mill TiAlN coated carbide from Ceratizit, 20mm in diameter with three flutes. In addition, only one insert was used because considering single tool for analytical purposes. Other than that, to avoid the influence of tool run out and facilitate the tools wear measurement. The experiment setup of tool and material was displays in Figure 2. Each experiment was conducted about three times and then used the final average value. The experiment setup is shown in Figure 3 and Figure 4. After the machining experiment, the machined block surface roughness and tool wear of these inserts were measured by using Mitutoyo portable surface roughness tester model SJ210 series as show in Figure 3. On the other hand, metallurgical microscope machine as shown in Figure 4 was also used to observe the tool wear length of those inserts for clearer micrograph image.

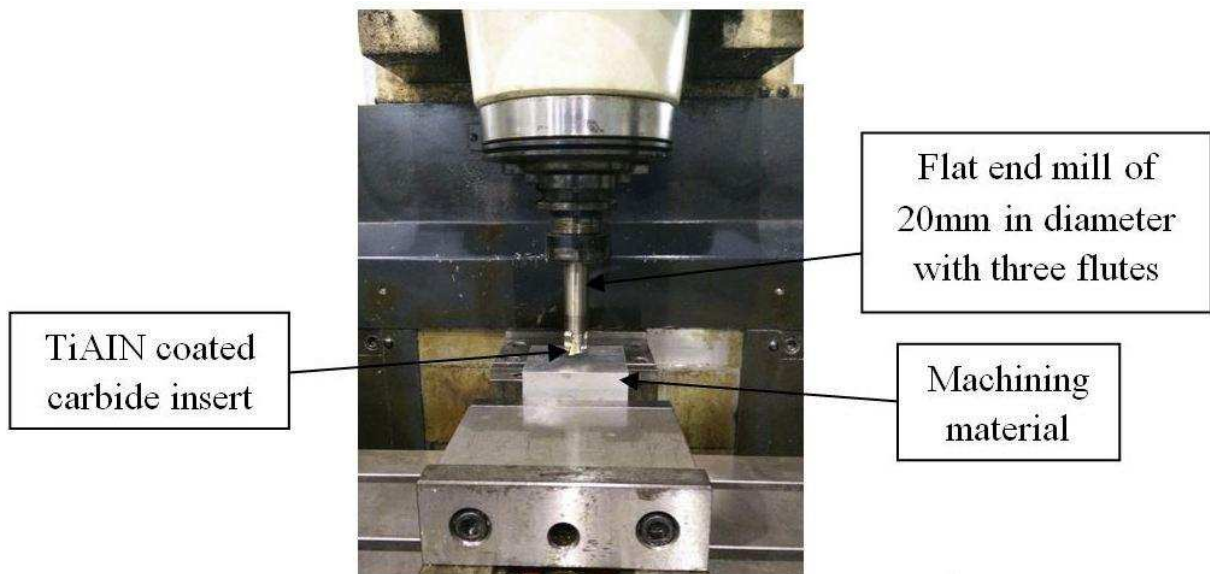


Figure 2: Experiment setup of tool and material

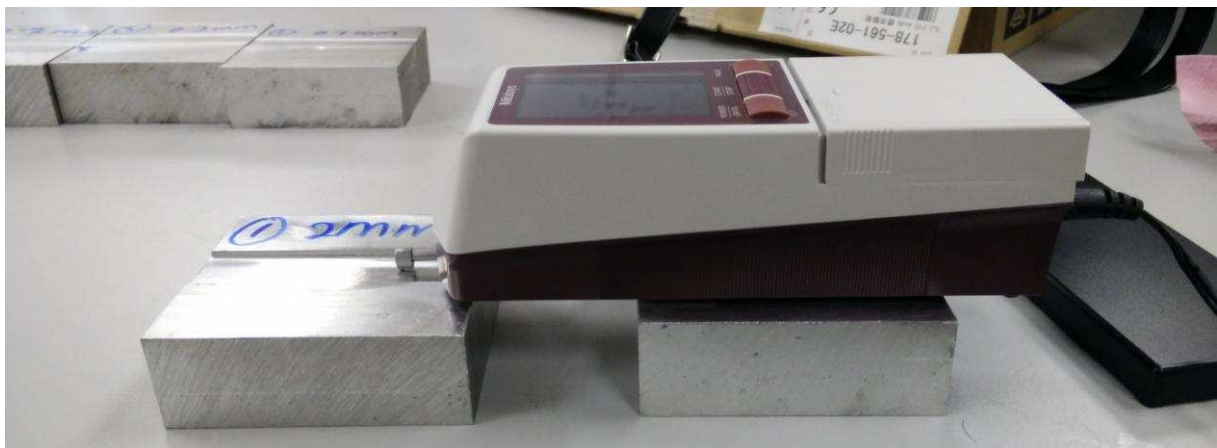


Figure 3: Mitutoyo portable surface roughness tester model SJ210 series



Figure 4: Metallurgical microscope machine

3.0 Result and Discussion

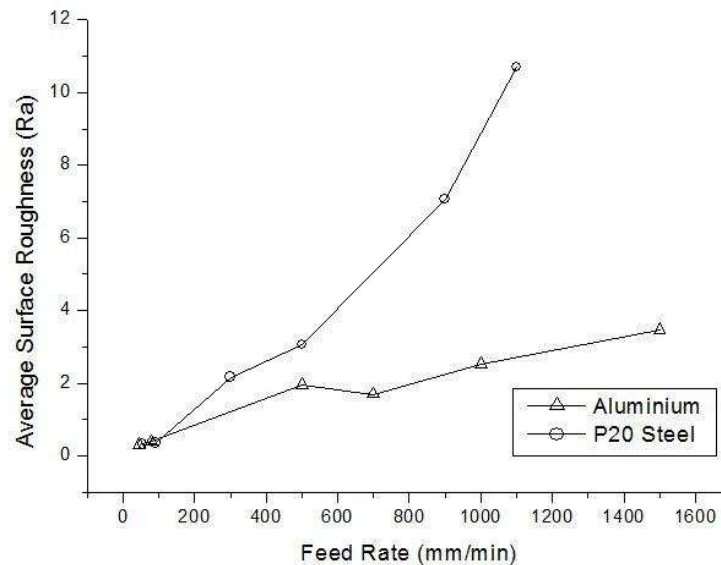


Figure 5: Average surface roughness vs varying combination of feed rate of first experiment for Aluminium and P20 Steel

Figure 5 shows that the average surface roughness value taken in first experiment for both materials, Aluminium alloy and P20 Steel using single slot of pocket machining where different combination of depth of cut and feed rate were used under constant material removal rate. This figure obviously prove that the feed rate strongly influence the surface roughness value to increase as when the feed rate is kept increasing while the depth of cut decreasing. Apart from that, according to the figure, the highest average surface roughness value for both materials is at lowest depth of cut 0.08mm and highest feed rate of 1500 mm/min for Aluminium and 1100 mm/min for P20 Steel. Furthermore, this also strongly proves that feed rate had contributed for the surface roughness value compare to depth of cut. This statement had agreed with Saikumar et al. (2012) that stated that as the cutting speeds and feed rates are increased, the rubbing action also become faster and more heat generated even though less contact time exists [9].

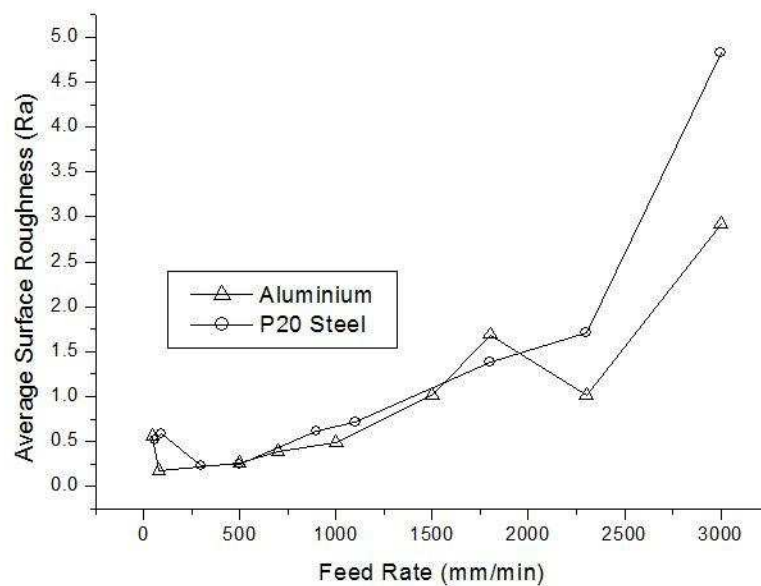
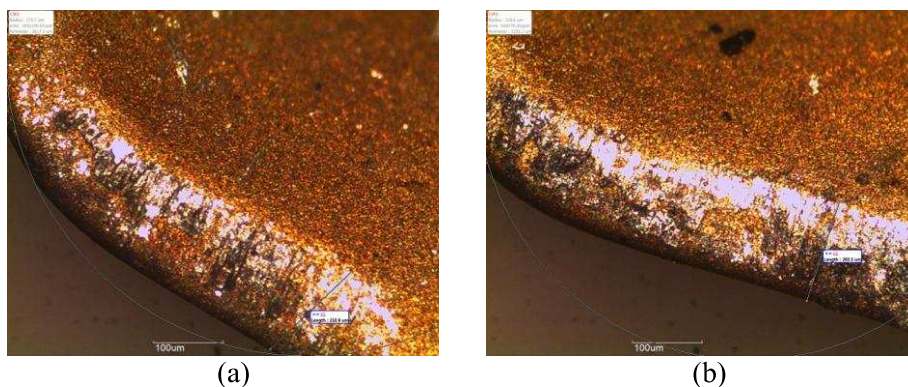


Figure 6: Average surface roughness vs varying combination of feed rate of second experiment for Aluminium and P20 Steel

Figure 6 displays that the average surface roughness value taken in second experiment for both materials, Aluminium and P20 Steel using ten slot of pocket machining where different combination of depth of cut and feed rate were used under constant material removal rate too. Obviously can see similar pattern from figure 6 compare with figure 5 where feed rate really influence the surface roughness value to keep increase as when the feed rate is kept increasing while the depth of cut decreasing. According to the figure 6, the highest average surface roughness value for both materials is at lowest depth of cut 0.03mm and highest feed rate of 3000 mm/min for Aluminium and P20 Steel. Although, the experiment is extended even to least depth of cut compare with first experiment, it still shows same pattern that the surface roughness value is keep increasing together with the increment of feed rate. Hence, this strongly proves that feed rate had contributed for the surface roughness value compare to depth of cut [15].

Figure 7 (a) and (b) and figure 8 (c) and (d) shows that no significant different in tool wear length were observed after using the metallurgical microscope machine for each experiment. The micrograph image taken indicates that feed rate and depth of cut did not influence the tool wear length when material removal rate, spindle speed and radial depth of cut are kept constant.



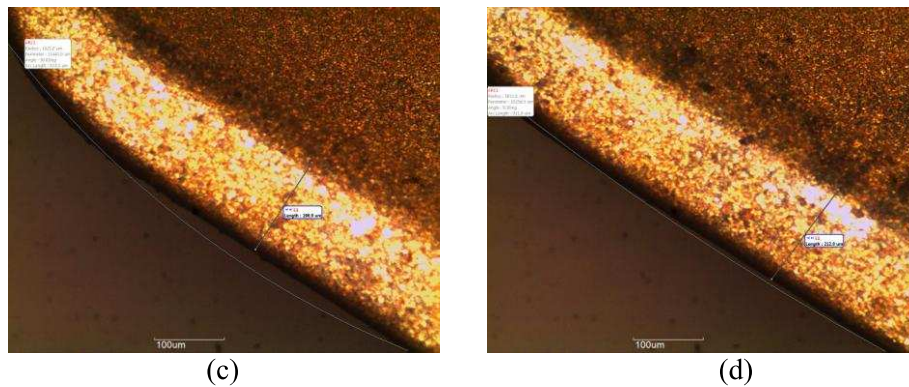


Figure 7: The metallurgical microscope image taken that displays tool wear length for first experiment (a) and (b) Aluminium; (c) and (d) P20 Steel: at varying combination of feed rate and depth of cut with constant material removal rate, spindle speed and radial depth of cut.

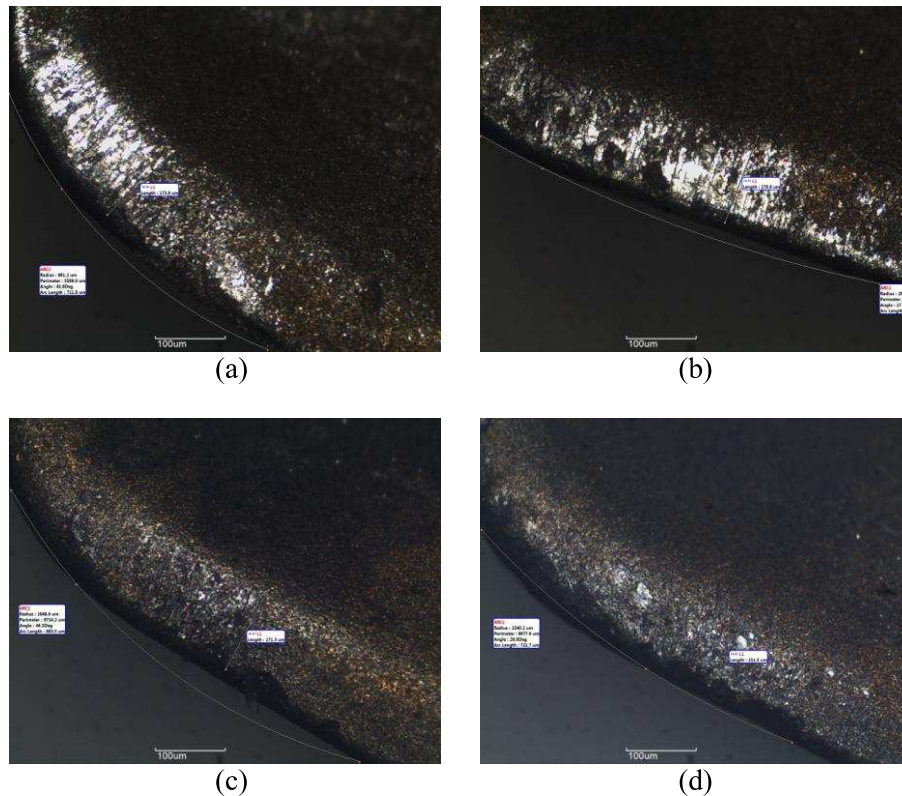


Figure 8: The metallurgical microscope image taken that displays tool wear length for second experiment (a) and (b) Aluminium; (c) and (d) P20 Steel: at varying combination of feed rate and depth of cut with constant material removal rate, spindle speed and radial depth of cut.

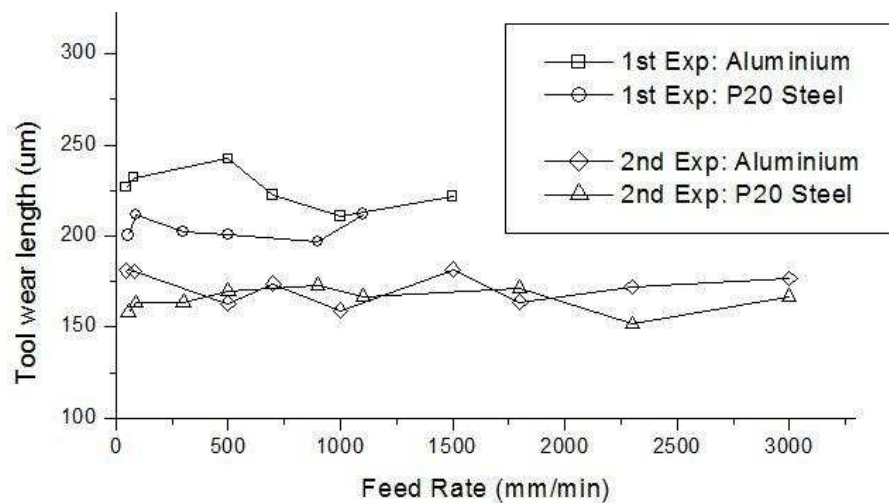


Figure 9: Tool wear length with different feed rate

Based on Figure 9 above, obviously mentioned that there is no significant influences in tool wear length when the material removal rate is kept constant throughout the experiment even though varies of depth of cut and feed rate was used. This is because the constant material removal rate that had been set for both experiment had balance the amount of heat generated at the tool. Moreover, the trend of tool wear length is quite similar for both materials in both experiments where no significant differences in tool wear length different were found. However, there is slightly different tool wear occurs in both types of materials due to their machining properties such as hardness, strength and so on. Tool wear is generally considered based on result gained from mechanical as thermo-dynamic wear and mostly abrasion and chemical as thermo-chemical wear and diffusion interactions between the workpiece and tool [16].

4.0 Conclusion

In this paper, through the experiments, with constant material removal rate, radial depth of cut and spindle speed, surface roughness value have been influenced by feed rate while depth of cut does not contribute at all. From the both experiment results given, the surface roughness value keeps incrementing when higher feed rate was used even the depth of cut had been reduced to shallow depth of cut, 0.003mm. Apart from that, when tested to least depth of cut and higher feed rate, 0.03mm and until 3000 mm/min respectively, the tool wear have shows no significant different for both materials in both experiments. Other than that, this proves that, material removal rate strongly contribute to tool wear rate because when the material removal rate was kept constant for both experiments, the tool wear rate too almost kept unchanged. In nutshell, high speed milling technique can be implementing in conventional milling machine with high feed rate, shallow depth of cut since there is no significant influence to tool wear rate by making material removal rate constant. On the other hand, HSM technique provides numerous benefits such as eliminate semi-finishing process and needs of coolant, reduce tool-load for finishing operation, better surface finish with good dimensional accuracy, cut off machining time and cost, production of smaller chip for easy cleaning purposes. Most importantly, this can boost the production of high quality and efficient materials and also contribute for higher productivity owing.

5.0 Acknowledgement

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6.0 References

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